

Hybrid Technique Used for Straight Line Detection

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Received on: 5 / 4 / 2010

Accepted on: 25 / 10 / 2010

ABSTRACT

Many techniques have been used in this research to detect straight line in digital image on the same samples. These techniques are:1-Hough Transform(HT), Developed Baron's Method (DBM)and-Genetic Developed Baron's Method(GDBM)

First technique was applied as it, while the second technique was applied after performing some modification in its algorithm. The third technique hybrid DBM (second technique) with GA, after performing the three techniques the accuracy and execution time for each technique is calculated. The experiment show that the hybrid technique relatively fast and it achieves high performance. It produces (90%) detection rate. MATLAB language has been used in the implementation of this software.

Keywords: digital images, genetic algorithm, Hough Transform, Straight Line Detection

استخدام تقنية هجينة لكشف الخط المستقيم

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تاريخ قبول البحث: 2010/10/25

تاريخ استلام البحث: 2010/4/5

المخلص

عدة تقنيات تم تطبيقها في هذا البحث لاكتشاف الخط المستقيم في الصورة الرقمية وعلى نفس النماذج من

الصور، هذه التقنيات هي: تقنية Hough Transform (HT)، وتقنية Developed Baron's Method (DBM) وتقنية Genetic Developed Baron's Method (GDBM)

طبقت التقنية الأولى كما هي، بينما تم إجراء بعض التعديلات لتطوير التقنية الثانية. أما التقنية الثالثة فهي تهجين ما بين الخوارزمية الجينية والطريقة الثانية المطورة. بعد تنفيذ الطرق الثلاثة تم حساب الدقة ووقت التنفيذ لكل طريقة وأظهرت النتائج أن الطريقة الهجينية المقترحة في هذا البحث سرعتها مقبولة وتحقق أداء عالي وأعطت نسبة اكتشاف للخط تصل إلى 90%. استخدمت لغة MATLAB في تنفيذ برامجيات هذا البحث.

الكلمات المفتاحية: الصور الرقمية ، الخوارزمية الجينية ، تحويل هوف، كشف الخط المستقيم

1- Introduction

The edge and line detection operators presented here present the various types of operators in use today. Many methods are implemented with convolution masks, and most are based on discrete approximations to differential operators.

The object features of interest include the geometric properties, histogram features, and color features, after extracting the features of interest, could analyze the image. Features extraction is part of the data reduction process and is followed by feature analysis. One of the important aspects of feature analysis is to determine exactly which features are important [1]

A.L Kesidis, N.papamarkos have proposed a new window based method for the inversion of the HT space. The proposed technique divides the original image to a rectangle window and then applies the IHT algorithm to each of them[2].

A parallel algorithm for HT on linear array with a reconfigurable pipeline bus system is represented by an approach proposed from Link Chen and Hongjian Chen supposed the number of Q-values to be considered in m for an image with $(n \times n)$ pixels[3].

"The Optimization of Edge and Line detections for forest image analysis", was suggested by Zhiling Long and Joseph Picone who designed an objective metric to evaluate the performance of edge and line detectors and then optimized the performance of their image analysis system using this metric. Their best system resulted in an error rate of 29%, and hand an acceptable insertion rate [4].

2- Hough Transform Method

Hough transform (HT) is a powerful tool for finding parameterized shapes in digital images. It is capable of detecting straight lines, circles, ellipses and other curves in both binary and gray scale image. The Hough transform is designed specifically to find lines, it is an algorithm that will take a collection of points, the primary advantage of the Hough transform is that it reduces the search time for finding lines and the corresponding set of points [5]. The original algorithm which was published by P.V.C. Hough quite a long time ago in 1959. It's procedure is based on the transformation of the original image pixel-by-pixel into the Hough-space adequate to the actual parameterization [6].

Hough transform based methods are robust over different image qualities since Hough transform converts a difficult global detection problem in image space into a more easily solvable peak detection problem in the Hough transform parameter space; therefore, they can deal with noise, degradation, and partial disconnection, even in complicated background [7]. In order to understand the Hough transform, first consider the normal representation of a line:

$$P = r \cos \theta + c \sin \theta \tag{1}$$

If have been a line in our row and column (rc) based image space, we can define that line by (P), the distance from the origin to the line a long a perpendicular to the line, and (θ) the angle between the r-axis and the p-line, for each pair of values of p and θ we have defined a particular line[3,7].show figure (1).

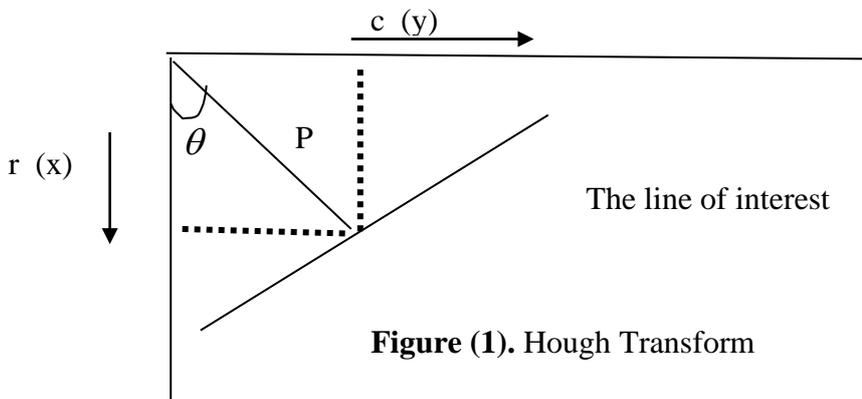


Figure (1). Hough Transform

In an image analysis context, the coordinates of the point(s) of edge segments (ie (x_i, y_i)) in the image are known and, therefore, serve as constants in the parametric line equation, while (P) and (θ) are the unknown variables we seek. If we plot the possible (P, θ) values defined by each (x_i, y_i) , points in Cartesian image space map to curves (i.e. sinusoids) in the polar Hough parameter space. This point-to-curve transformation is the Hough transformation for straight lines. When viewed in Hough parameter space, points which are collinear in the Cartesian image space become readily apparent as they yield curves which intersect at a common (P, θ) point. [1]

3- Baron's Method

Baron Lic suggested a new method for detecting straight line in image depending on Hough transform. This method supposed that there are straight lines for all (P, θ) values on screen, and calculated the range of the corresponding actual existing line with suppose line if the rate of corresponding is high. This refers to finding line in current (P, θ) , and the following detail explain of this method [8]:-

Let us define the distance d_i in image space, which is Euclidean, as the minimum distance between point P_i and the line represented by the parameters P and θ , as follows:

$$d_i = \| \mathbf{d}_i \| = \sqrt{(x_i - x_o)^2 + (y_i - y_o)^2}, \quad \mathbf{d}_i = \mathbf{p}_i - \mathbf{p}_o$$

$$\mathbf{P}_i = [x_i, y_i]^T,$$

$$\mathbf{p}_o = [x_o, y_o]^T \quad (2)$$

Where \mathbf{P}_i is the position vector of point p_i and \mathbf{P}_o is the position vector of the closest point of the line to point p_i , this point is readily obtained as follows:

$$\mathbf{P}_o = \left\{ \begin{array}{ll} x_o = p, \quad y_o = y_i & \text{if } \theta = j\pi \quad \forall j = -1, 0, 1 \\ x_o = x_i \sin^2 \theta - y_i \sin \theta \cos \theta + p \cos \theta & \text{otherwise} \\ y_o = y_i \cos^2 \theta - x_i \sin \theta \cos \theta - p \frac{\cos^2 \theta}{\sin \theta} + \frac{p}{\sin \theta} & \end{array} \right. \quad (3)$$

The extraction can be formulated as the following optimization problem:

$$Z(P, \theta) = \sum_{i=1}^n \frac{1}{(1 + d_i)} \rightarrow \max_{p, \theta} \quad (4)$$

Subject to the constraints

$$0 \leq p \leq (l_x^2 + l_y^2)^{\frac{1}{2}}, \quad -\pi \leq \theta \leq +\pi \quad (5)$$

Where n is the number of points in the set and d_i is given by equations (2), (3). This equation makes it possible to find a line, which has the maximum likelihood in the set of points while searching in the parameter space. This equation has many local optima and is equivalent to Hough transform.

This method was represented by algorithm as follows:

1- The value of P and θ would be specified as:

$$0 \leq p \leq (l_x^2 + l_y^2)^{1/2}, \quad -\pi \leq \theta \leq +\pi$$

l_x, l_y : represent matrix dimensions

2- Calculate the function :

$$Z(P, \theta) = \sum_{i=1}^n \frac{1}{(1 + d_i)} \rightarrow \max_{p, \theta}$$

where n : represents number of white pixels. p : represents the P ., θ : represents the θ .
 d_i : Eclides distance.

2-1 Find p_o value whenever:

If $\theta = -\pi$, or $\theta = 0$, or $\theta = +\pi$. Then $x_o = p, \quad y_o = y_i$

Otherwise

$$x_o = x_i \sin^2 \theta - y_i \sin \theta \cos \theta + p \cos \theta$$

$$y_o = y_i \cos^2 \theta - x_i \sin \theta \cos \theta - p \frac{\cos^2 \theta}{\sin \theta} + \frac{p}{\sin \theta}$$

$$2-2 \quad d_i = \sqrt{(x_i - x_o)^2 + (y_i - y_o)^2}, \quad d_i = p_i - p_o$$

where : p_i : is the position vector of actual line.

p_o : is the position vector of fanciful line.

$$2-3 \quad \text{newsum} = \text{oldsum} + 1/(1 + d_i)$$

2-4 Repeat the previous steps (from step 2-1) for all θ values, then Find maximum value of function between all θ values.

3- Repeat steps (from step 2-1) until all P values are finished.

4-Applied Methods

In this research different methods have been used to detect straight line: the first method is traditional (prevailing used) represented by Hough Transform Method (HTM). The second method is newest method (rarely used) which is represented by Baron's method (BM), the third method is Baron's development method (BDM), and the last method is intelligent method using genetic algorithm (GA).

4-1 Hough Transform Method (HTM)

The Hough Transform Method (HTM) has been used to detect the straight lines as it has been applied to each texture separately with an angle of about [0-180]. All the pixels, which are located on rectitude and at the same angle, have been detected. The method mentioned in section (2) has been followed as well as the application of the equation (1) to all the image's pixels. We also obtained a matrix with three columns where the first dimension represents the number of the pixels located on rectitude, the second dimension represents the straight line inclination angle and the third dimension is the x axis of the pixel.

4-2 Baron's Method (BM)

Baron's Method is one of the newest straight line detection method, this method depend on (HTM) concepts, but it applies straight-line equation in polar (HT). It supposes that there is a straight line in each place in search space. The corresponding between image's pixels and fanciful line's pixel (in polar HT space) has been calculated. If the corresponding is high that indicated to find straight line in location(p, θ) and the converting to Cartesian and found (x, y) that equivalents (P, θ) in polar HT.

This method has a good property, represented by accuracy of the straight lines number and the accuracy to find locations of the line. At the same time it is suffering from a number of weak points. We can specify it as following points :

1. The method hasn't any ability to detect vertical straight line in search space.
2. The line has been detected in this method consists of a number of pixels which are more than available number of pixels that make actual line.

4-3 Developed Baron Method (DBM)

Some development and modification has been performed to the previous method to process a weak points and obtained better results and more accuracy; it is called Developed Baron method (DBM), which consists of the following steps:-

- 1- The value of P and θ would be specified as :

$$0 \leq p \leq (lx^2 + ly^2)^{\frac{1}{2}}, \quad -\pi \leq \theta \leq +\pi$$

lx, ly : represent matrix dimensions

2- Calculate the function:

$$Z(P, \theta) = \sum_{i=1}^n \frac{1}{(1 + di)} \quad \rightarrow \max_{p, \theta}$$

where: n : represents number of white pixels., p : represents the P.

θ : represents the θ ., di : Eclides distance .

2-1 Find p_o value wherever :

2-1-1 IF $\theta = -\pi$, or $\theta = 0$, or $\theta = +\pi$

Then $x_o = p$, $y_o = y_i$

Else

2-1-2 If $\theta = \pi/2$ then $x_o = x_i$, $y_o = y_i$

Otherwise

$$x_o = x_i \sin^2 \theta - y_i \sin \theta \cos \theta + p \cos \theta$$

$$y_o = y_i \cos^2 \theta - x_i \sin \theta \cos \theta - p \frac{\cos^2 \theta}{\sin \theta} + \frac{p}{\sin \theta}$$

2-2 $di = \sqrt{(x_i - x_o)^2 + (y_i - y_o)^2}$, $d_i = p_i - p_o$

where : p_i : is the position vector of actual line.

p_o : is the position vector of fanciful line.

2-3 check if $d_i=0$ or $acc \leq 1/(1 + d_i) \leq 1$ (acc is accuracy rate)

then $newsum = oldsum + 1/(1 + d_i)$

2-4 Repeat steps (from step 2-1) for all θ values and find maximum value of function.

3- Repeat steps (from step 2-1) for all P values.

The additional steps that develop the Baron Method are:

- 1- The step (2-1-2) gives the ability of detecting vertical straight line, by checking θ value ($\theta = \pi/2$) and find values of x_o , y_o (location of vertical line)
- 2- The step (2-3) gives the ability of obtaining a better corresponding rate (between actual line and fanciful line) by checking (di) value, when $d_i=0$, this means perfect corresponding has been done for pixel otherwise, when $d_i \neq 0$ the corresponding has been checked if it is around the specific user value this means corresponding has been done, otherwise pixel will be ignored .

4-4 Genetic Developed Baron Method (GDBM)

We can observe by executing the two traditional methods that the ratio of their accuracy is not satisfactory enough. The first method detects the straight line, but it does not provide accuracy as regard to the number of the actual straight lines because it gives fanciful lines near to the actual line. Accordingly we have significantly more straight lines than the actual number.

The second method offers a relatively accurate numbers of lines after having a suitable decision on the ratio of the symmetric pixels and this depends on the trial and error procedure being used. Notice that the execution of this method takes time. In order to get more efficient execution the GA has been used since the genetic algorithm is

considered as one of the means for achieving optimal output for finding out the optimal solution or the nearest to the optimal as well as the ability to deal with research of huge and complicated area. According to what have been mentioned above we arrived at a solution where we can hybridize the BDM with GA and because this method offers relatively good and accurate results as well as the objective function enables us to use it in the genetic algorithm. The following are the steps that specify the genetic algorithm elements used with the GBDM method.

a- Creating Initial Population

The population consists of a number of individuals detected by the algorithm designer and according to the nature of the problem. In this work population has been detected by 50 chromosomes. These chromosome consists of a number of values (genes) whose lengths are detected according to the problem. The chromosome, in this work, has been represented by the following Figure:



Figure(2): Chromosome Configuration

The figure of chromosome in this work consists of two genes(P gene, θ gene), where the range of P gene is between (0-142) and the range of θ gene is between (0-180) degree .

b- Encoding

The chromosome which was explained in the previous step represented by a binary encode. Each gene is represent by 9 bit to accommodate a maximum value for P and θ (the maximum value of $\theta=180$ and the maximum value of P =142).

c-Evaluation of The Chromosome

In the genetic algorithm the chromosome is evaluated by the fitness value in order to check the kind of the solution, therefore, each chromosome (which is born in an initial population or through the antecedent generations) has a fitness value related to the objective function .In this work, individual is evaluated by the number of the pixels. Individual with high pixels will get high corresponding, whenever the number of pixels increase we will gets the best result ,which means that objective function is maximum function and thus the fitness is equal to the objective function as follows:-

$$\text{Fitness value} = \text{objective value} = Z(P, \theta) = \sum_{i=1}^n \frac{1}{(1 + di)} \rightarrow \max_{p,\theta}$$

Fitness degree depending on threshold is specified by a user. This value is different from an image to another. The principle of trial and error is being used to detect this value until we arrive at the best decisions.

d- Selection

The Elitism method[]has been used to select a number of the current population individuals to represent the parents of antecedent generation. The selection from the individuals to represents the parents depend on the value of the fitness function for every individual. In this work a number of good chromosome has been copied to antecedent generation, the number has been specified by five chromosomes (best

chromosome has been copied to antecedent). The rest of the parent are selected by the Roulette Wheel Selection method.

e- Crossover

Crossover between parent has been done to produce a new generation that represents the beginning of antecedent genetic cycle. Two-point crossover has been used to suitable chromosomes length, the two point position are located randomly and the crossover ratio was decided to be (0.9) .

f-Mutation

Mutation has been applied to get a chromosome that possesses new characteristics which have not been formed before from the previous generation, in order to extend the possible solution area. The flip bit mutation method has been used, the mutation ratio was decided to be (0.3) after trying different values.

g-Stop Criterion

The stop criterion in the GA decides whether the algorithm continues researching or stop. The stop criterion is depend on two approaches: generations number and fitness threshold. Each fitness value for chromosome is compared with a fitness threshold and according to the result of comparison the number of the straight lines in the image is specified, when specific number of straight lines are detected, stop the calculations..

4-5 Algorithm Evaluation

To evaluate the proposed algorithm, we calculate the average precision using the following equations:

$$\text{average precision} = \frac{\sum_{i=1}^n \text{precision}_i}{n} \quad \text{number of slices contain lines} \quad (6)$$

$$\text{precision}_i = \frac{(\text{Detected_lines})_i}{\text{Slice}_i_lines} , \quad 1 \leq i \leq n \quad (7)$$

The equation (7) calculate slice's accuracy that contain straight lines, the term (slice_i_lines) represents the actual number of straight line existence in slice i, while the term (detected_lines) represents the number of detected straight lines in slice i ,and n represents a number of slices that contain straight lines. The equation (6) calculates slice's accuracy average of image by divided the summation of accuracy rate for all slices on slices number.

4-6 Discussion of results

The line detection based on (HTM ,DBM,GDBM) are carried out for the same sample (the slices are obtained after segmentation step). A threshold of (50 pixels) for the pixels number are used to indicate a straight line. Table(1) shows the obtained results for slices 6, 7, 8 and 9.

It is clear from the Table(1) that the three methods are association by detected lines in the same slices. The table also shows that the number of straight lines that are detected using (DBM,GDBM) methods are closed to actual lines number, while the HTM method gives very far results from actual lines number .

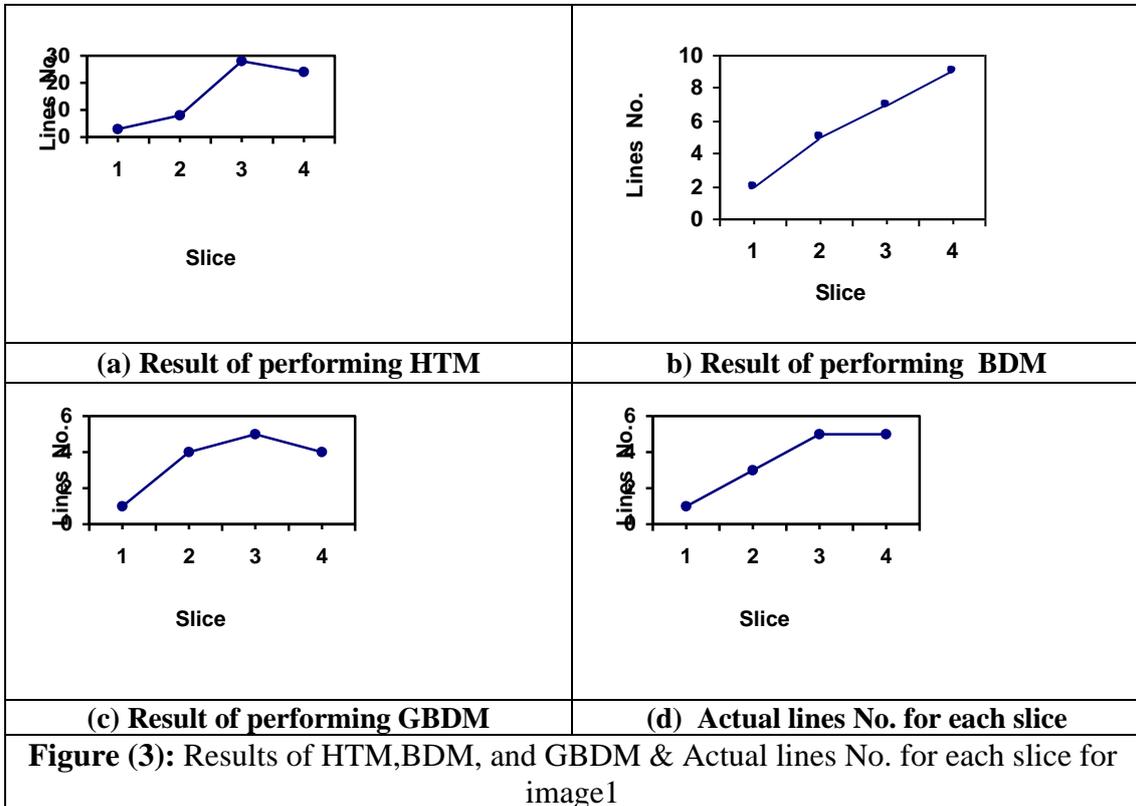
The comparison between HTM, DBM,GDBM and actual lines number is shown in Figure (3) graphs a, b, c, d respectively, we notice that the results of graphs (c and d) are

closed to each other, because they use the same technique (objective function), and notice that a graph c is a little bit closed to graph d, from the direction of actual number of lines and estimated by the algorithms and it could be considered the optimal result.

Table (1): Line Detection methods results

Slice No.	Methods	Detected Lines No.
Slice 6	HTM	3
	BDM	2
	GBDM	1
	Actual Line No.	1
Slice 7	HTM	8
	BDM	5
	GBDM	4
	Actual Line No.	3
Slice 8	HTM	28
	BDM	7
	GBDM	5
	Actual Line No.	5
Slice 9	HTM	24
	BDM	7
	GBDM	4
	Actual Line No.	5

The Figure (4) represents the average precision for each method by applying the equations mentioned in section (4-5), the GDBM give perfect detection (precision=1). So the proposed hybrid method (GDBM) is considered the best method for the line detection.



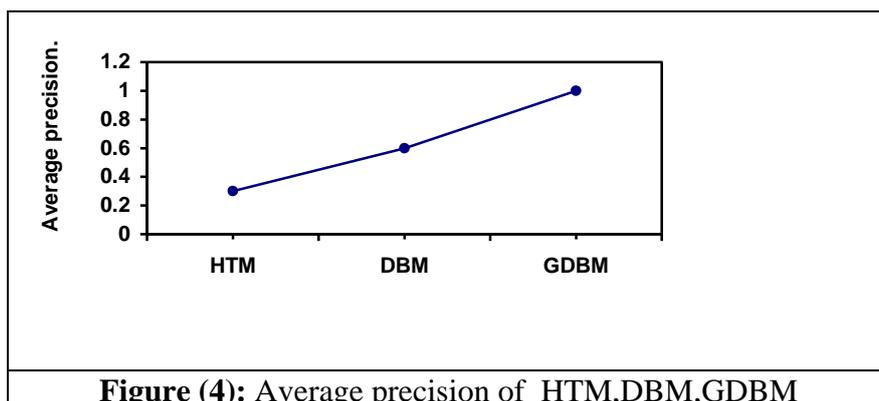


Figure (4): Average precision of HTM, DBM, GDBM

6-4 Evaluation Execution time

The execution time of straight line detection using the proposed hybrid technique and another traditional method for the same image sample are carried out (all slices that are obtained after Canny edge detector step which was done experintly) and the results are shown in Figure (5)

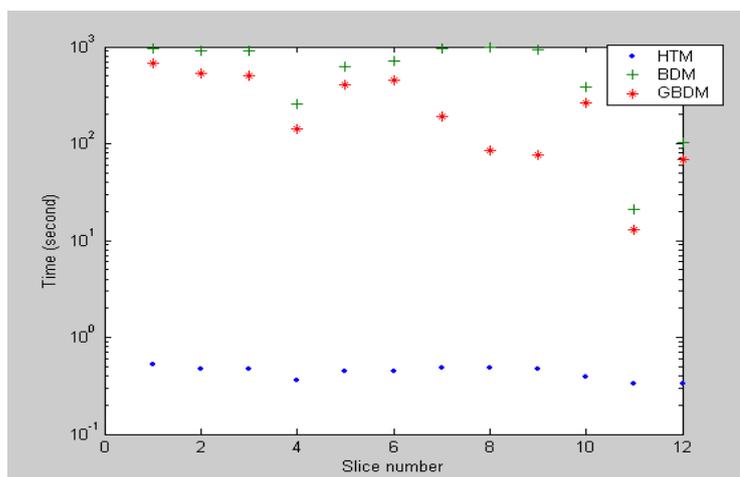


Figure (5): Execution time for HTM, DBM, and GDBM

It is clear from Figure (5) that the execution time for the HTM method is less than 1 second, while the execution time for GDBM method is in the range of (20-800) second, and the execution time for DBM is in the range of (40-999) second. Notice that GDBM combined the benefit of the accurate result with acceptable execution rate, therefore this method represents the best compared to another two methods. To give more details about the results applied methods, detected lines will be redrawn again for each slices. These can be clearly seen in Figures (6), (7), (8).

CONCLUSIONS

- 1- Applying HT principle to extract features of straight lines gives best results when it joined with other techniques.
- 2- Applying Baron's method gives another approach to detect straight line in digital images, applying some modification gave positive effect on the results and get high correspond between detection line and actual line.
- 3- The Baron's Development Method and Genetic algorithm produce efficient results and high performance (acceptable execution time and 95% precision).

Future Works

- Applying the techniques used in this research with hybridized Neural Network techniques to get high performance
- Use the GDBM method in medicine fields.

1- Results of performance HTM

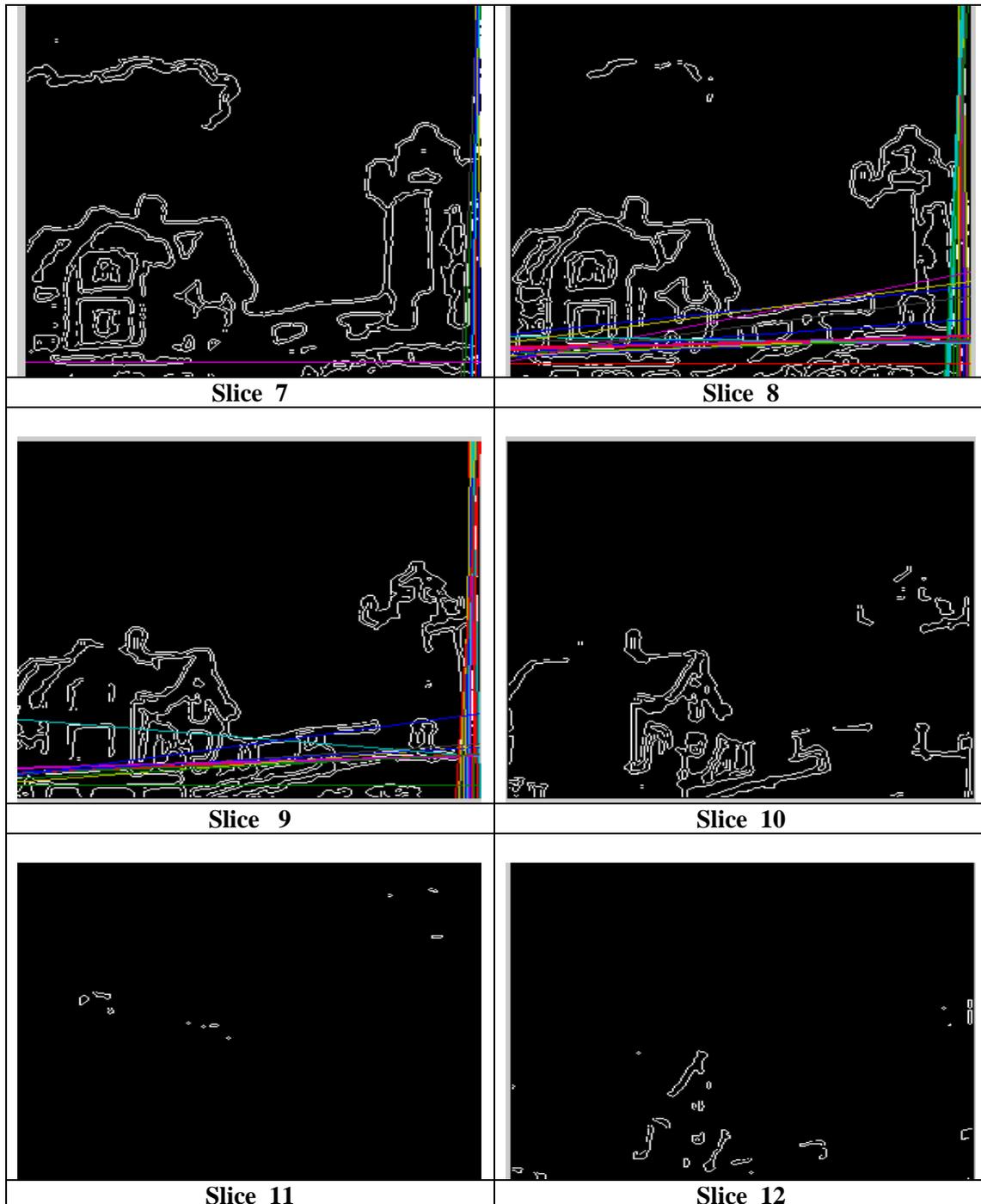
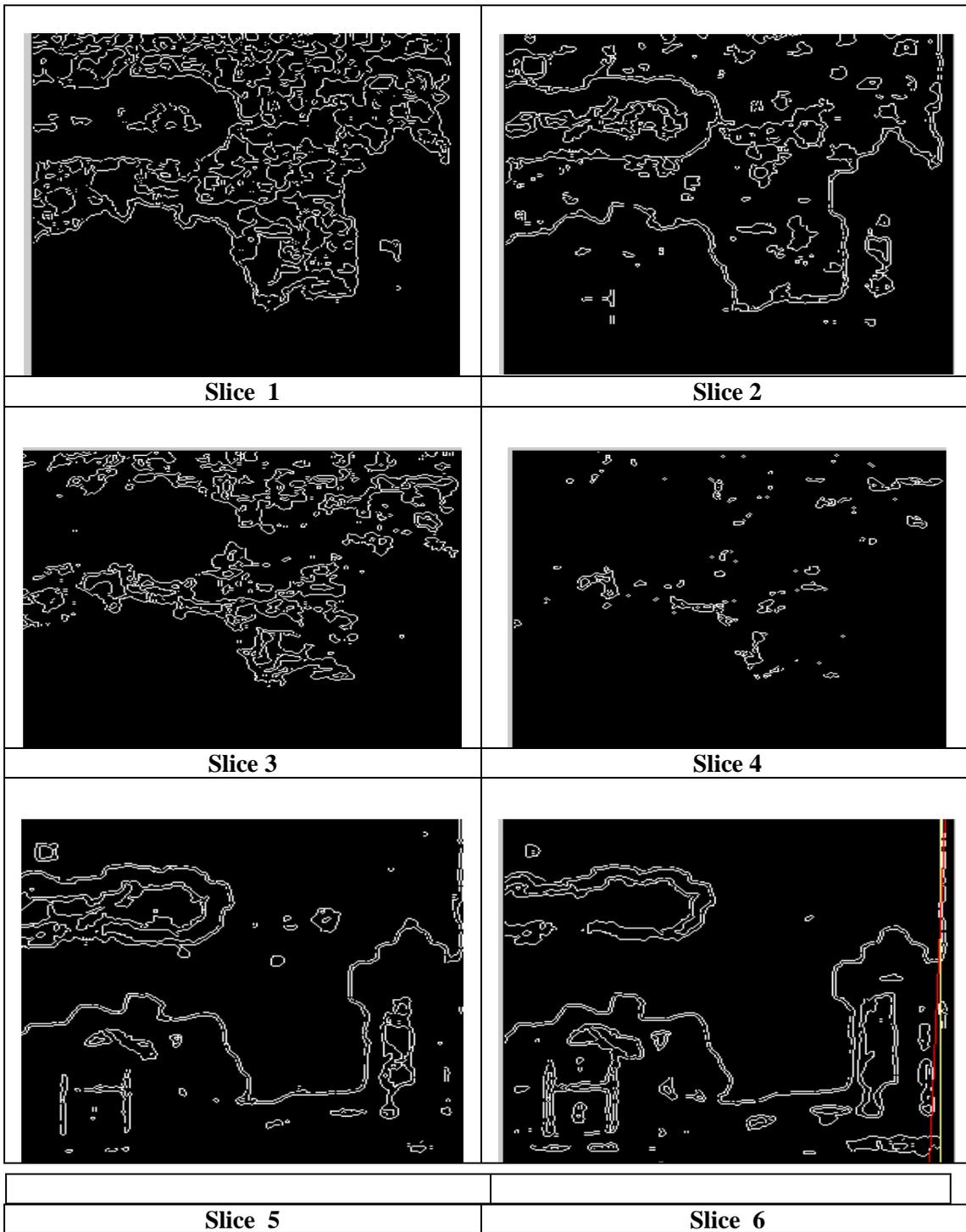


Figure (6): Results of HTM for image1

1-Results of performance DBM



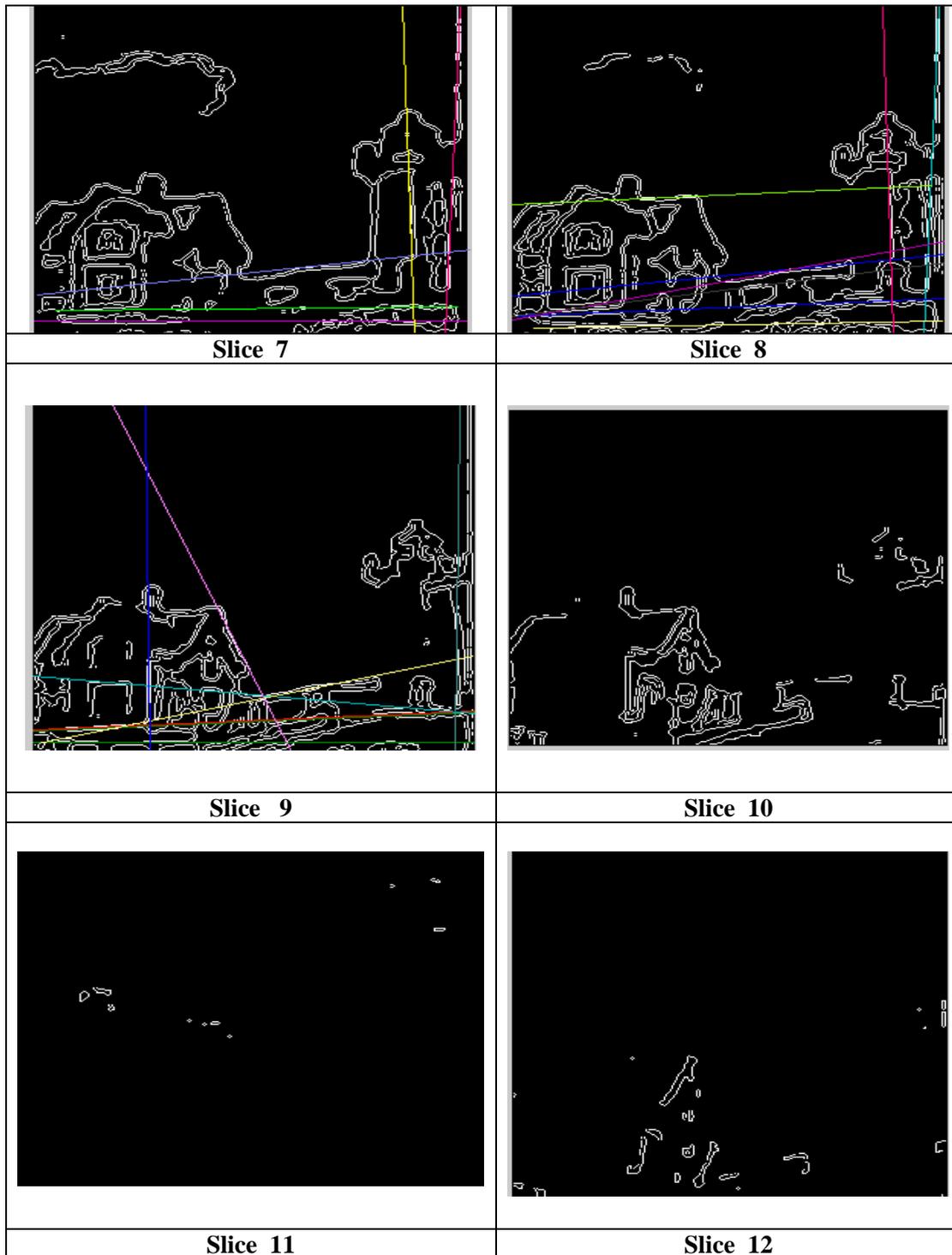
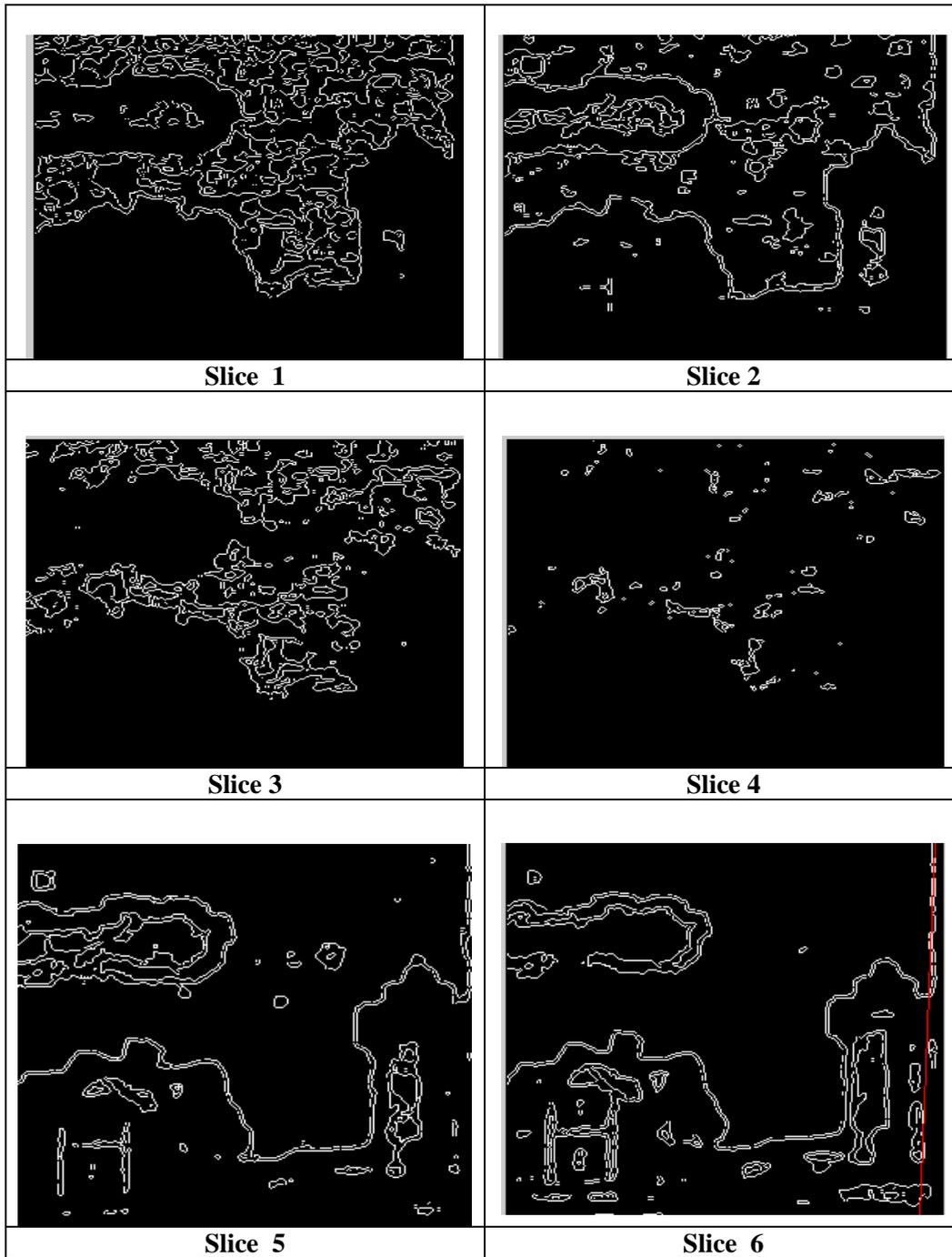


Figure (7): Results of BDM for image1

1- Results of performance GDBM



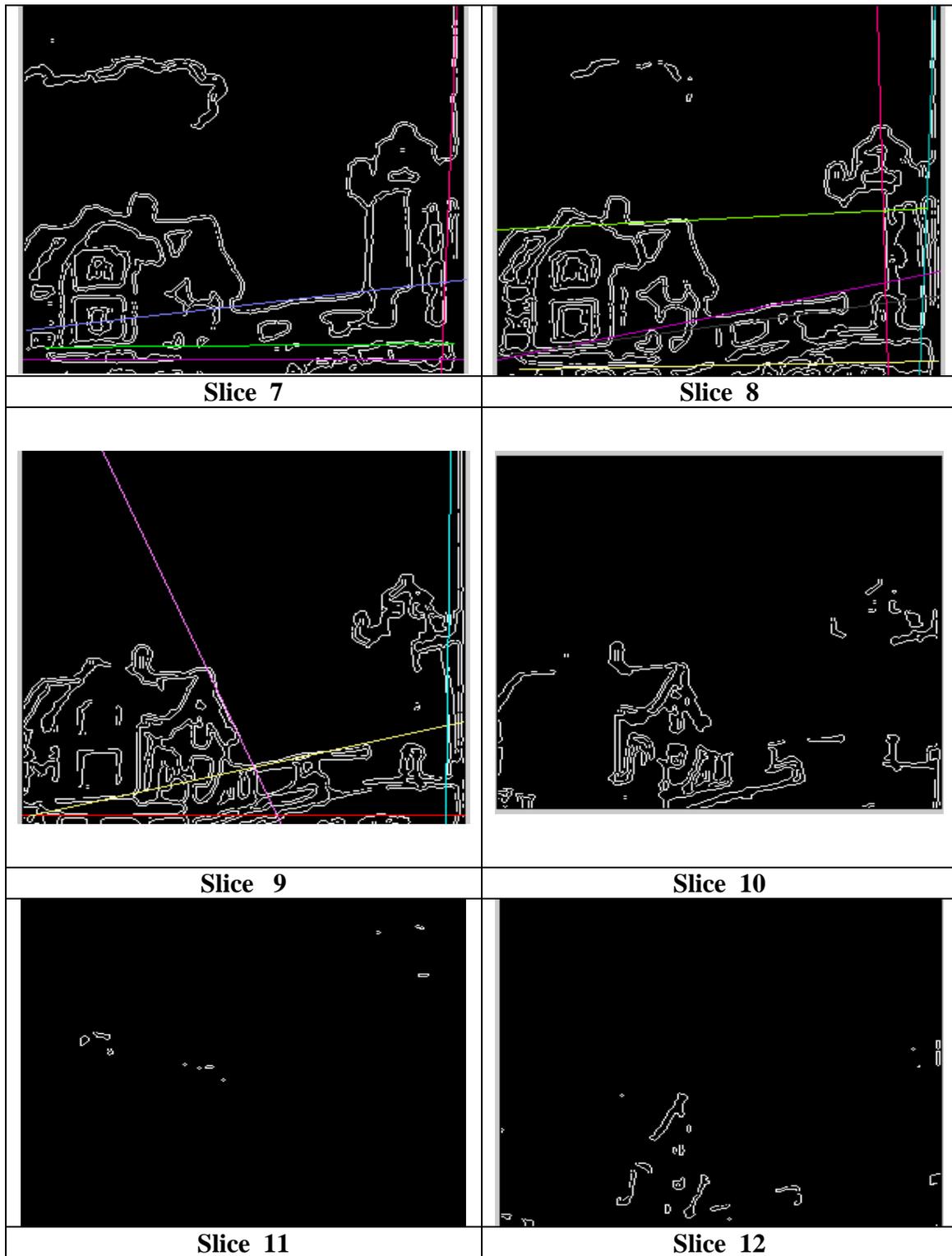


Figure (8) : Results of GBDM for image1

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